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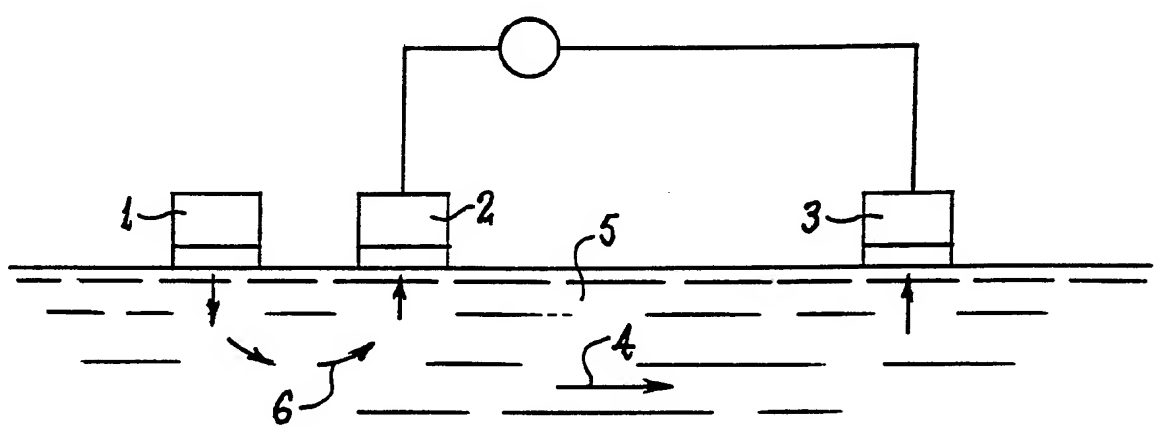

(57) Abstract

A detector for detecting flow of fluid (4) having a heater (1) operable to transfer thermal energy (6) to a body of fluid (5) with which the detector is associated and first (2) and second (3) temperature sensors each of which is operable to respond to the temperature of the fluid body. The second temperature sensor (3) is spaced from the first temperature sensor (2) so that there exists a difference in the response of each temperature sensor at least while no fluid flows past the detector. The detector also includes means operable to detect a change in the difference in the response whereby any such change is representative of a change in the flow rate of the fluid body. Also disclosed: a pumping system in which the pump motor is controlled by a fluid pressure responsive means and by a flow detector having timing means. An isolating means for a flow detector comprising a baffle element having walls with apertures controlling the fluid flow.

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"FLOW SENSOR AND CONTROL SYSTEM"

This invention relates to fluid flow systems and is particularly concerned with flow sensors as used in such systems. The invention is also concerned with other aspects concerning control of a pump or other flow generating device as used in such a system.

A flow sensor according to the invention is especially useful in fluid flow systems of the kind including a pump which draws fluid (e.g., water) from a supply source and delivers that fluid to a service outlet by way of a pressure accumulator. Systems of that kind are commonly used to supply water from a dam or a holding tank. It will be convenient to hereinafter describe the invention with particular reference to systems of the foregoing kind, but it is to be understood that the invention has other applications.

The pump of a system of the foregoing kind needs to be protected from dry-running - i.e., a situation in which there is no water available in the supply source, but the pump is nevertheless continuing to operate. Such dry running can cause serious damage to the pump and is to be avoided. For that purpose, the pump system may include a flow sensor which is intended to detect absence of water through the pump and produce a signal which results in the pump being shut down. Flow sensors as known prior to the present invention have not been sufficiently reliable for a variety of reasons.

It is an object of the present invention to provide a fluid flow sensor which operates on the basis of a temperature comparison. That is, a comparison between a reference temperature or temperature gradient, and the temperature of fluid flowing past a heat source such as a heater whereby heat is transferred to the fluid body.

It is a further object of the invention to provide such a sensor which remains effective in spite of variations in mains power supply voltage and/or ambient temperature of the fluid body.

Another object of the invention in a preferred form is to provide a sensor which may be as free as possible from variation or ageing of thermally conductive adhesives

used during manufacture of the sensor.

Yet another object of the invention in a preferred form is to provide such a sensor having effective power control means so as to ensure relatively consistent operation of the sensor over a wide variation of power supply voltage.

Another object of the invention, in a preferred form, is to provide such a flow system with means for ensuring that the pump is primed at commencement of a pumping operation.

According to one aspect of the invention, there is provided a flow sensor having a heater and temperature responsive means which is operable to respond to temperature of a fluid body. The heater and the temperature responsive means may be relatively arranged so that the temperature responsive means detects transfer of heat from the heater to a fluid body with which the temperature responsive means is associated. In such an arrangement, the fluid temperature detected by the temperature responsive means is an indicator of the rate of fluid flow past the sensor. That is, a high detected temperature indicates little or no flow, whereas a low detected temperature indicates high flow.

It is preferred that there is no direct transfer of heat between the heater and the temperature responsive means, which may be a thermistor, for example. Such prevention of heat transfer may be achieved by the provision of any suitable form of thermal isolation minimizing direct transfer of heat between the heater and the temperature responsive means.

In one embodiment of the invention transfer of heat between the heater and the temperature responsive means may be via a close thermal link. In this embodiment the temperature responsive means measures the temperature of the heater or a variable directly related to the heater temperature.

In an alternative embodiment of the invention transfer of heat between the heater and the temperature responsive means may be via a loose thermal link. In this

embodiment a heater is used to locally heat water or fluid in the system and the temperature responsive means is located adjacent to this local source of heat. The temperature responsive means senses the temperature loss in the fluid caused by fluid movement or flow. The temperature responsive means measures heated fluid temperature with first order independence of the quality of the thermal link between the heater and temperature responsive means.

There may be circumstances under which ambient temperature of the fluid varies to such an extent as to disturb effectiveness of the sensor. In one form of the invention, means may be provided to compensate for such ambient temperature variation. Such compensating means preferably includes a thermistor, or other temperature responsive means, which detects and responds to ambient or base temperature of the fluid, and feedback means which produces a signal characteristic of that detected temperature and applies that signal to compensate the temperature responsive means and/or to control of the heater. In embodiments utilizing a close thermal link between the heater and the temperature responsive means the arrangement may be such that a substantially constant temperature differential is maintained between the heater and the fluid ambient temperature.

In embodiments utilizing a loose thermal link between the heater and the temperature responsive means to compensate the heater for ambient temperature variations may be dispensed with and the heater may be arranged to operate with constant power input. Heater temperature may still depend on the quality of the thermal link between the heater and temperature responsive means although the temperature rise of the fluid (and hence the output of the sensor) may be independent (to first order) of the quality of the thermal link.

In a preferred arrangement, the heater may be of the electrical resistance type and the temperature responsive means may be rendered operable by connection to an electrical power source. The heater may be included in a power supply circuit for the temperature responsive means,

and may function as a mains voltage dropping component thereby eliminating the need for an expensive power transformer.

In a fluid flow system incorporating a sensor as described, it is preferred that the sensor is isolated from the influence of spurious flow. By way of example, isolating means may be operative to isolate the sensor from the influence of flowing air, but not flowing water. Such isolating means thereby ensures that the desired sensor response occurs under flow conditions of the kind which are intended to be monitored.

The isolating means may comprise a baffle that at least alleviates the effects of fluid turbulence on the flow sensor. The baffle may be adapted to provide the sensor with an environment which is substantially free of turbulence and vortices. The baffle should not restrict the sensor from being subjected to fluid flow above a predetermined minimum rate. One purpose of the baffle is to localize turbulence in a relatively short distance. The baffle may include a relatively long space for containing and/or dissipating turbulence and a relatively short space which is substantially free of turbulence. In one form the long space may include converging means such as a frusto-conical portion. The short space may include a cylindrical portion. Alternatively the converging means may comprise a stepped cylindrical portion.

The converging means preferably includes apertures within a wall or walls thereof. The converging means is operative to absorb kinetic energy of a vortex within a minimum length without converting the energy into turbulent flow. Energy absorption may be achieved by causing the vortex to converge on its axis within the converging means of the long space. Selection of aperture sizes and positions along the wall or walls of the converging means combined with optimum wall thickness may ensure vortexing is confined within the long space. Strategic positioning of apertures near the downstream end of the long space may allow fluid to return to the vortex.

Although the isolating means is described in association with the flow sensor described herein it may

be used separately therefrom or in conjunction with other arrangements in which it is desired to reduce or alleviate the effects of fluid turbulence.

According to another aspect of the invention, there is provided a fluid supply system including a pump and a pressure accumulator connected to the output side of the pump. Pump control means is also provided and includes pressure responsive means and first and second timer means. The pressure responsive means detects falling pressure in the accumulator and may cause operation of the pump at a predetermined minimum pressure. The first timer means functions to ensure continued operation of the pump after power up for a first period of time, say 30 to 60 seconds, even though water (or other fluid to be pumped) is not passing through the pump. That is, the first timer means overrides, temporarily, any flow sensor which may be provided in the system to terminate operation of the pump under certain flow conditions (e.g., no flow). The first timer means ensures that the pump can be primed before the flow sensor becomes effective to control the pump.

Where water is not passing through the pump because of eg. a fault condition, the second timer means is provided to run the pump for a second relatively short time period, say 5 to 15 seconds, after the pressure responsive means detects falling pressure. At expiration of the second time period, the second timer means operates to turn off the pump. This may ensure that the pump does not run in a dry state for an excessive period.

The fluid supply system of the present invention may include thermal switch means to switch off the pump or associated control system in the event that fluid or water temperature exceeds a predetermined threshold. This may be desirable because fluid or water temperature in excess of the predetermined threshold may be detrimental or may cause damage to the pump and/or its associated control system. The thermal switch means may be adapted to turn off the pump eg. by disabling the pump motor switch when fluid or water temperature exceeds the abovementioned threshold temperature.

The thermal switch means may include latch means

which may be triggered at the threshold temperature. The latch means may maintain the pump switch in a disabled state until the latch means is reset. The latch means may be reset eg. by removing and re-applying a control voltage to the latch means.

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings wherein:

Figure 1 is a representation of a flow sensor according to the present invention and utilizing a loose thermal link;

Figure 2 is a representation of a pump system utilizing a flow sensor according to the invention;

Figure 3 is a block diagram of a pump control system incorporating a flow sensor of the invention;

Figure 4 is a circuit diagram of a pump control system including the flow sensor of figure 1 and incorporating the features of Figure 3;

Figure 5 is a representation of a flow sensor according to the invention and utilizing a close thermal link;

Figure 6 is a block diagram of a heater control incorporating a voltage dropping power supply;

Figure 7 is a circuit diagram of the heater control and power supply of Figure 6;

Figure 8 is a circuit diagram of a pump control system including the flow sensor of Figure 5 and incorporating the heater control circuit of Figure 7;

Figure 9 shows one form of baffle means which may be used to isolate the flow sensor from the effects of spurious flow; and

Figure 10 shows one form of thermal switch means.

The particularity of the drawings is not to be understood as superceding the generality of the preceding description of the invention.

Figure 1 shows, in diagrammatic form, a flow sensor incorporating one aspect of the invention. That sensor includes a heater 1, flow indicating means 2 and ambient

temperature compensating means 3. The flow indicating means 2 and the ambient temperature compensating means 3 each comprises or includes temperature responsive means, and in a preferred arrangement hereinafter described in greater detail, each such temperature responsive means is formed by a thermistor or similar device. It will be convenient to hereinafter refer to the flow thermistor 2 and the ambient thermistor 3.

Each of the three components, 1, 2 and 3, may be mounted on a respective support such as a sheet or substrate of ceramic or other insulating material. Alternatively, they may be mounted on a common support, but in such a case it is preferred to provide at least some degree of thermal isolation between the heater 1 and the flow thermistor 2, for a reason hereinafter explained. In one form thermal insulation may be provided by a barrier of silicone or the like between respective sheets or substrates of ceramic on which the heater and flow thermistor 2 are mounted.

The ambient thermistor 3 is shown downstream from the heater 1 relative to the direction of fluid flow as shown by the arrow 4, but it could be located upstream of the heater 1 if desired. In any event, the ambient thermistor 3 is preferably positioned so as to detect the temperature of the body of fluid 5 at a location substantially unaffected by transfer of heat from the heater 1 to the fluid body 5. That is, it is the intention of the ambient thermistor 3 to detect and respond to the ambient or base temperature of the fluid body 5.

It is necessary for the flow thermistor 2 to be located relatively close to the heater 1 so as to be responsive to dissipation of heat into the fluid body 5 from the heater 1. Assuming that heater 1 operates on substantially constant power the temperature of the portion of the fluid body 5 adjacent to the heater 1 will be relatively low if the rate of fluid flow past the heater 1 is high, and will be relatively high if the fluid flow rate is low. The flow rate indicating function of the flow thermistor 2 may be impaired if there is

excessive transfer of heat between the heater 1 and the thermistor 2 other than through the fluid body 5 as represented by the arrows 6. It is for that reason that it is preferred to provide at least some degree of thermal isolation between the heater 1 and the thermistor 2, and in a simple form that can involve spacial separation of those components as shown in Figure 1.

The ideal situation as shown in figure 1 may not be a practical possibility. In practice it is probable that an interface such as a substrate connects heater 1 and thermistor 2. That interface/substrate (eg. copper or ceramic) forms a heat sink to ensure adequate transfer of heat from heater 1 to thermistor 2. In some embodiments it may be convenient to mount all components ie. heater 1 and thermistors 2 and 3 upon a common substrate.

Since the heater 1 must transfer heat to the fluid body 5, and the thermistors 2 and 3 must respond to the temperature of that body, it is necessary for each of those three components to have direct or indirect contact, or close association, with the fluid body 5. Indirect contact or association through an electrically insulating material such as ceramic is usually preferred.

The flow thermistor 2 is connected to an appropriate reference so that the extent of rise or fall in detected temperature can be determined. In the arrangement shown in Figure 1, the reference is the ambient thermistor 3, and that may be a direct or indirect line of reference.

Figure 2 diagrammatically illustrates a pump system incorporating the flow sensor as described. That system includes a pump 7, a motor 8 to drive the pump, and an accumulator 9 on the output side of the pump.

Pressure responsive means 10 detects a fall in the pressure within the accumulator 9 below a predetermined level, and responds by causing operation of the pump motor switch 11 so that the pump 7 is started. Water, for example, is thereby drawn from the supply source 12 and pumped, by way of the accumulator 9, to a service outlet. The flow sensor 13 is positioned on the output side of the accumulator 9 as shown, and responds to flow as previously described. Flow sensor 13 may be arranged to sample flow

as shown or it may be arranged such that all flow passes through sensor 13. A barrier or baffle 14 is provided adjacent the sensor 13 so as to protect the sensor against the influence of spurious flow as previously referred to.

Flow sensor 13 alternatively could be located in front of pump 7 and that location being a low pressure location may be of advantage in some circumstances. In further embodiments flow sensor 13 may be located between pump 7 and accumulator 9.

In the event that the sensor 13 detects a low or no flow situation, switch 11 which may be a thyristor or silicon controlled rectifier will be operated to shut down the pump 7.

Figure 3 is a block diagram which illustrates one form of pump system incorporating a flow sensor according to the present invention. The blocks 15 represent the mains power input to the system. The block 16 represents the mains power switch, and the block 17 represents a switch which is responsive to detection of a fall in pressure in the system. Each of the switches 16 and 17 is connected to respective first and second timers 18 and 19 which are in turn connected to a temperature sensor 20 incorporating flow thermistor 2 and ambient thermistor 3 in a bridge circuit. Block 21 represents a mains voltage feedback circuit adapted to provide a compensating voltage to the temperature sensor 20. The compensating voltage is adapted to remove the effect of mains voltage fluctuations and consequent changes in heater output. Block 22 represents the basic flow switch and may comprise a voltage comparator connected to respective arms of the bridge circuit of temperature sensor 20.

When switch 16 is actuated on initial power up or subsequent restoration of power, timer 18 functions to ensure that pump 7 will continue to operate for a satisfactory period - e.g., 30-60 seconds. That ensures adequate priming of pump 7 without interruption by the influence of the flow sensor. At the end of that period the flow sensor including heater 1, temperature sensor 20 and flow switch 22, is activated and imposes its influence on the system. In the event that a fault condition

arises and switch 17 is actuated to cause operation of pump 7 because of detected low pressure in the system, the second timer 19 functions to ensure that the pump will operate for a relatively shorter period eg. 5 to 15 seconds. This ensures that the pump does not run in a dry state for an excessive period. Thus the role of timers 18, 19 is to run the flow sensor or to override it.

In the circuit of figure 4 the flow thermistor 2 is represented by thermistor element R13 and ambient thermistor 3 is represented by thermistor element R12. On power up capacitor C_2 belonging to the first timing means, and capacitor C_3 belonging to the second timing means are uncharged and input pins 5, 6 of op. amp 23 which may be one half of a dual FET device type TL082, are initially at positive rail voltage V^+. As the time constant associated with the first timing means (resistors R_1, R_2 and capacitor C_2) is chosen to be about 4 to 5 times greater than the time constant associated with the second timing means, (capacitor C_3 and resistors R4, R5) the voltage at pin 6 drops more quickly than the voltage at pin 5.

When the voltage at pin 5 is higher than the voltage at pin 6, output pin 7 is high. The above time constants may be chosen such that the voltage at output pin 7 of op. amp 23 stays high for approximately 45 seconds. When pin 7 turns high pin 2 of op. amp 24 (other half of device TL 082) is also high and output pin 1 of op. amp 24 is consequently low. A low output at pin 1 activates an oscillator circuit including capacitor C_7. The oscillator circuit causes capacitor C_7 to be discharged periodically via transistors T_2, T_3 into switch 11 comprising a triac. Triac switch 11 is turned on by the resultant chain of pulses and connects mains power to motor 8 (not shown) which in turn causes pump 7 (not shown) to run.

The voltage dividers formed by resistors R1/R2 and R4/R5 are chosen such that the steady state voltage at input pin 5 is just below than the steady state voltage at input pin 6. Hence when capacitors C_2, C_3 are fully charged the voltage at output pin 7 is low.

The pressure responsive means 10 is represented in Figure 4 by switch SW. When pressure in accumulator 9 drops switch SW is shorted causing full rail voltage to pass across capacitor C_4 turning transistor T1 on temporarily. This pulls capacitor C_3 to ground charging it fully. With capacitor C_3 fully charged input pin 6 of op. amp 23 goes low causing pin 7 of op. amp 23 and pin 2 of op. amp 24 to go high. Consequently pin 1 of op. amp 24 goes low and the pump runs.

With transistor T_1 off capacitor C_3 discharges with the time constant associated with the second timing means, causing pin 7 of op. amp 23 to return low in about 10 seconds. A low voltage at pin 7 activates the flow sensor which comprises a bridge circuit made up of thermistor elements R12, R13 and resistors R15, R16 and R8. The bridge is trimmed via resistor R15 so that it balances when thermistor element R13 is cool and is indicative of an acceptable flow rate in the system. Minimum flow at pump switch may be approximately 2.5 litres/min with water temperature between 2-50°C and approximately 3 litres/min with water temperature between 50-70°C.

Feedback resistor R18 also influences balance of the bridge circuit. The function of resistor R18 is to shift the balance point of the bridge whenever the supply voltage changes thereby compensating the bridge circuit for the change in heater output due to supply voltage fluctuations.

The pump will keep running until low flow is sensed. Low flow causes thermistor element R13 to heat up causing the bridge circuit to unbalance sending the voltage at pin 2 of op. amp 24 low, since thermistor element R13 exhibits a negative temperature coefficient. This drives pin 1 high turning off the oscillator circuit and triac switch 11, and pump 7 stops. Positive feedback from pin 1 to pin 4 holds the pump off. The pump does not run until pressure in accumulator 9 drops and switch SW closes again retriggering pin 7 high and pin 1 low and causing the pump to run again.

If pressure in accumulator 9 is low or switch SW

becomes jammed in the closed position and the pump turns off because of a fault condition, it will not run because switch SW remains shorted and cannot retrigger pin 7. However pin 7 may be retriggered by disconnecting mains power and reconnecting it again. Diode D3 (actually a transistor connected in diode configuration for low leakage) then discharges capacitor C_2 and upon power being reconnected pin 5 remains high until capacitor C_2 charges to the steady state voltage determined by voltage dividing resistors R1, R2. The time constants described above are sufficient to hold pin 5 above pin 6 for about 45 seconds and the pump runs during this period notwithstanding that a fault condition exists. The pump then stops because the fault condition will keep the bridge circuit unbalanced.

Because capacitor C8 is charged to full rail voltage it causes a wetting current to discharge through switch SW each time switch SW opens and closes. This keeps switch SW clean and avoids the need for (expensive) gold contacts.

Figure 5 shows, in diagrammatic form, a flow sensor incorporating another aspect of the invention. That sensor includes a heater 1, flow indicating means 25, ambient temperature compensating means 26 and heater temperature indicating means 27. The flow indicating means 25, ambient temperature compensating means 26 and heater temperature indicating means 27 each comprises or includes temperature responsive means, and in the preferred arrangement hereinafter described, each such temperature responsive means is formed by a thermistor or similar device. It will be convenient to hereinafter refer to the flow thermistor 25, the ambient thermistor 26 and the temperature thermistor 27.

As in the previous embodiment each of the four components, 1, 25, 26 and 27, may be mounted on a respective support such as a sheet or substrate of ceramic or other insulating material. Alternatively, they may be mounted on a common support. The ambient thermistor 26 is shown downstream from the heater 1 relative to the direction of fluid flow as shown by the arrow 4, but it could be located upstream of the heater 1 if desired.

It is preferable that the flow thermistor 25 be located between the heater 1 and the ambient thermistor 26 so as to be responsive to dissipation of heat into the fluid body 5 from the heater 1. Operation of flow thermistor 25 relies on the fact that the temperature gradient existing between the heater 1 and the ambient thermistor 26 will be relatively low if the rate of fluid flow past the heater 1 is high, and will be relatively high if the fluid flow rate is low. The flow rate indicating function of the flow thermistor 25 may be impaired if there is transfer of heat between the heater 1 and the Flow thermistor 25 other than through the fluid body 5 as represented by the arrows 28. It is for that reason that it is preferred to provide at least some degree of thermal isolation between the heater 1 and the thermistor 25.

Since the heater 1 must transfer heat to the fluid body 5 (directly or via a substrate/interface), and the thermistors 25 and 26 must respond to the temperature of that body, it is necessary for each of those three components to have direct or indirect contact, or close association, with the fluid body 5. Indirect contact or association through an electrically insulating material such as ceramic is usually preferred.

The flow thermistor 25 is connected to an appropriate reference so that the extent of rise or fall in detected temperature can be determined. In the arrangement shown in Figure 5, the reference is the ambient thermistor 26, and that may be a direct or indirect line of reference. Alternatively, the reference may be the temperature thermistor 27, and again the line of reference may be direct or indirect.

A connection exists between the heater 1, the ambient thermistor 26 and the temperature thermistor 27 for the purpose of ambient temperature compensation. The connection is such as to establish a reference which is characteristic of the temperature gradient existing between the heater temperature and fluid ambient temperature as it exists at any one point in time. That gradient reference enables the system to compensate for

variations in fluid ambient temperature, and in particular provides a convenient reference for the flow thermistor 25. It is to be understood that the heater temperature and ambient temperature referred to may not be the actual temperatures, but may be represented by something which is characteristic of or corresponds to the respective temperatures.

It is also to be understood that other modes of operation of the arrangement of figure 5 are possible. Thus the roles of one or more of flow thermistors 25-27 could be interchanged. For example heater 1 could be associated with any one of thermistors 25-27 for the purpose of establishing an appropriate temperature reference or temperature gradient.

Reliability of operation of the flow sensor described can be impaired if the voltage applied to the heater 1 varies significantly. One particular arrangement which avoids or at least alleviates that problem is described below by reference to the block diagram of Figure 6.

Figure 6, includes the heater 1, thermistors 26 and 27, switch means 29 for the heater 1, control means 30 connected between the thermistors 26 and 27 and the switch means 29 for controlling modes of operation of the heater 1. The entire circuit is connected to a source of mains electrical power. The two lines 31 and 32 between the heater 1 and the switch means 29 represents the two modes of operation of the heater 1 previously referred to.

It is a feature of the arrangement shown in Figure 6 that the heater 1 forms part of the power supply circuit for the thermistors 26 and 27. It is a further feature of the arrangement that means is provided whereby the voltage applied to the thermistors 26 and 27 is maintained at a substantially constant level.

Under the high current mode of operation (through line 31), the regulating means 33, which may be a zener diode, functions to maintain the voltage at the output of switch means 29 at a predetermined level. Under the low current mode of operation (through line 32), the switch means 29, which may be a voltage biased silicon controlled

rectifier or thyristor, responds to the load on the thermistors 26 and 27 so as to provide a current flow through the heater 1 as necessary to maintain a predetermined voltage to thermistors 26 and 27. The part of the circuit through which power is supplied to the thermistors 26 and 27 functions as a voltage dropping power supply circuit.

Figure 7 shows a heater control circuit which incorporates the voltage dropping circuit of Figure 6. The block marked A in Figure 7 represents the aforementioned voltage dropping power supply circuit which supplies DC power to the thermistors 26 and 27. In that regard, the heater 1 is represented by resistance R11 and the switch means 29 of Figure 6 is represented by the SCR Q1. Thermistor 26 is represented by the reference R13 and thermistor 27 is represented by the reference R12.

In the heater circuit of Figure 7, the resistance heater R11 is connected in series with an AC mains supply, and that connection is under the control of SCR Q1 which when triggered drives a DC output voltage limited by the reverse breakdown voltage of zener diode D3. A further diode D4 connects the DC voltage appearing across zener diode D3 to smoothing capacitor C1. In that regard, the diode D3 corresponds to the regulating means 33 of Figure 6. A further diode D4 may be included, depending on the selection of Q1. The circuit composed of the foregoing is essentially a voltage dropping and rectifying network, and the inclusion of SCR Q1 allows control of current flow to the capacitor C1. The heater R11 functions as a dropping resistance with the zener D3 limiting the output voltage, and the diode D4 and capacitor C1 providing additional rectification and filtering respectively.

Figure 8 illustrates application of the Figure 7 circuit to a flow sensor as described which is arranged to control operation of a pump. In the Figure 8 arrangement, the heater control circuit includes a comparator IC1/A and a bridge circuit, the arms of which each comprises a resistor and a thermistor. One arm comprises the resistor R1 and the thermistor R12, and the other arm comprises the resistor R3 and the thermistor R13. In a practical

application of the sensor, the thermistor R12 is placed in thermal proximity to the heater R11 and provides a feedback, representing the temperature of the heater R11, to one input of the comparator IC1/A. It will be appreciated that other means could be employed for that feedback function. The thermistor R13 is preferably placed in a thermally decoupled position relative to heater R11 - i.e., it is not open to thermal influence by the heater - and in a practical application is arranged so as to provide a signal representing the ambient temperature of a fluid body, and that signal is transmitted to a second input of comparator IC1/A.

It will be appreciated that the ambient temperature signal is usually not fixed, but "floats" up and down according to the prevailing ambient temperature of the fluid with which the sensor is associated.

Alternatively, if ambient temperature compensation is not required, the thermistor R13 may be replaced by a fixed (or variable) resistance element. The value of the fixed (or variable) resistance element would then determine the signal to the second input of comparator IC1/A. When ambient temperature compensation is required, the bridge elements R12, R13, R1 and R3 are chosen such that the bridge will balance when there exists a temperature differential T1 between thermistors R12 and R13, say 20°C. Comparator IC1/A may be arranged to enable the gate of SCR Q1 via diode D2 as the bridge passes its balance point.

The above arrangement will control the temperature of the heater R11 such that it will "track" ambient temperature as measured (detected) by the thermistor R13. That is, the temperature of the heater to be maintained at a substantially steady temperature differential T1 above ambient temperature of the fluid so as to result in a predictable temperature gradient for reference purposes.

Comparator IC1/A controls operation of the DC power supply in two modes;

(i) where pin 7 of IC1/A is low, and

(ii) where the voltage at pin 7 rises to switch SCR Q1 to be permanently triggered.

In mode (i), which may require an output voltage of say 9 volts, the diode D2 may have approximately 10 volts applied to it. That output voltage will drop if the voltage across capacitor C1 falls, so causing R2 to fire the thyristor Q1, whereby current is caused to drive through SCR Q1 for say one half a cycle. That current flow will charge the capacitor C1 and then be directed through the zener diode D3 to "dump" excess current. With an increase in output voltage across the capacitor C1, SCR Q1 will cease conducting. In this mode of operation input current from the AC mains supply will be just sufficient to maintain a charge on capacitor C1. In the example illustrated, that may be substantially between 0.1 milliamps to 8 milliamps (RMS).

In mode (ii) of operation, in which SCR Q1 is permanently triggered by the comparator IC1/A, half-wave rectified current will flow through the resistance heater R11 and will be limited to a maximum which is determined by the total impedance of the circuit and the mains supply voltage. In the particular circuit shown, maximum current flow is approximately 30 milliamps (RMS).

Control of SCR Q1 is via diodes D3, D2, resistor R2 and the output of comparator IC1/A. Resistor R2 provides a trigger current to the gate of SCR Q1 which provides "start-up" to an otherwise inert circuit. If the comparator IC1/A output (pin 7) is low, SCR Q1 operates in mode (i). When the voltage on capacitor C1 drops, the combination of D2, D3 and R2 provides gate current causing conduction of SCR Q1 until C1 voltage rises again.

If the comparator IC1/A output is high, resistor R2 provides continuous gate current, keeping SCR Q1 fully on. This means that SCR Q1 is operating in mode (ii). The heating control circuit may be disabled by forcing the cathode of diode D1 to a logic low, thereby forcing comparator IC1/A to a low output and disabling the gate of SCR Q1. In the arrangement of Figure 8, the cathode of diode D1 will be low when a no flow condition is sensed and pressure switch P1 is not actuated.

The diagram of Figure 8 shows an example control system which utilises a flow sensor, as previously

described, to turn off a supply pump (not shown) driven via motor 8 upon detection of an unacceptably low flow rate.

The control system of Figure 8 incorporates a heater control circuit as described with reference to Figure 7. The flow sensor includes comparator IC1/B connected to a bridge circuit whose arms comprise thermistors R13 and R14 and resistors R3 and R4/R15/R16. Thermistor R14 is physically positioned intermediate thermistors R12 and R13 relative to the direction of fluid flow, and corresponds to the flow thermistor 25 of Figure 5. Resistors R15/R16 are connected to a sliding switch SW adapted to short the resistor R16, or both the resistors R15 and R16, out of the bridge circuit. Switch SW may be used for adjusting flow rate sensitivity.

Bridge elements, R13, R14, R3 and R4/R15/R16 are chosen or adjusted such that the bridge will balance when there exists a fixed temperature differential T2 between thermistors R13 and R14 which does not exceed the temperature differential T1 between thermistors R12 and R13 (20°C in the example given). That is reasonable because the thermistor R14 is placed intermediate the thermistors R12 and R13.

For example, when the thermistor R14 is placed midway between the thermistors R12 and R13 and the rate of fluid flow is at an acceptable level, the temperature differential T2 between thermistors R13 and R14 may be adjusted (e.g., by means of the switch SW) such that it is approximately equal to one half of the temperature differential T1 between the thermistors R12 and R13 (i.e., T2 = 1/2 T1).

Should the rate of fluid flow decrease below the noted acceptable level the temperature differential between the thermistors R12 and R13 will rise <u>above</u> T1, say to T1+ΔT. Assuming that a substantially constant thermal gradient exists between the thermistors R12 and R13, the temperature differential between thermistors R13 and R14 will also rise to approximately 1/2 (T1+ΔT) = T2+<u>ΔT</u>. That is greater than the balance temperature T2 of the bridge circuit associated with the flow sensor and

will cause the comparator IC1/B to trigger to a high output. As a consequence, the pump motor 8 will be switched off via the latch formed by NAND gates IC2/A and IC2/B, pump motor triac switch Q3 and gate trigger triac switch Q2. Q2 is a sensitive gate triac minimizing current source requirements of CMOS NAND gate IC2/B and the power supply.

As comparator IC1/B requires a pull up current to enable its output, the pump motor must run for some minimum time when activated as set by the RC time constant of a timing circuit comprising resistor R8, capacitor C4 and buffer IC2/D (typically about 45 seconds). Provided this minimum time has elapsed, the pump motor can then be turned off immediately flow cessation has been sensed. That time constant may be established to ensure priming of the pump as hereinafter discussed.

In operation, flow will be sensed by pressure in a fluid reservoir falling and actuating pressure switch P1. This will set the latch and turn on pump motor 8. This is initally independent of the flow sensor output (IC1/B) as there can be no pull-up current provided to its open collector output until the minimum run time has elapsed as determined by the timing circuit.

If pressure switch P1 remained actuated, i.e., there existed continuous low pressure, and no flow was sensed, this would be indicative of a liquid "no head" condition at the pump and the pump must be turned off. This is ensured as both latch outputs will be forced low by the action of the pressure switch and flow sensor. This condition is stable and can maintain the motor off and the heater control circuit on.

The pressure switch input is protected from external noise sources by a filter comprising resistors R5, R6 and capacitor C2.

The latch output, IC2/B, drives motor 8 on or off via triac switch Q3. Resistor R9 sets the trigger current for the more sensitive gate triac Q2, which in turn sets, via resistor R10 the larger trigger current drive required by the motor triac switch Q3.

Figure 9 shows the flow sensor 13 positioned within

flow coupling element 34. Fluid enters coupling element 34 from the top and exits at the right as indicated by the arrow 35. The lower opening provides a service access and is plugged in use. The flow sensor comprises heater 1, flow thermistor 2 and ambient thermistor 3 as previously described. Thermisters 2 and 3 are printed as a matched pair on a single piece of ceramic and are separated by snapping the ceramic. This avoids the need to trim the thermistors in circuit.

To alleviate the effects of fluid turbulence upon the flow sensor 13 a frusto-conical baffle 36 is inserted into coupling element 34 as shown in broken outline. Baffle 36 is adapted to provide flow sensor 12 with an environment which is substantially free of turbulence and vortices. Baffle 36 does not restrict the sensor from being subjected to fluid flows above a predetermined minimum.

Apertures 37 included within the converging portion of baffle 36 are adapted to absorb kinetic energy of a vortex without converting the energy into turbulent flow. Apertures 37 comprise slots as shown or they may be substantially circular. Apertures 38 allow fluid to return to the vortex and are important to proper functioning of the baffle. Wall thickness of the baffle should be sufficient to avoid shear of flow over the external surface of baffle 35. Generally speaking a relatively thin wall may be used where apertures 37 are small. Wall thickness may be increased as the size of apertures 37 increases. Heater 1 and flow thermistor 2 are positioned over the cylindrical or forward portion of baffle 35 which is substantially free of turbulence.

Referring to Figure 10 the thermal switch means includes a temperature responsive element in the form of thermistor R4. Thermistor R4 forms a voltage divider with trim resistor R3. The junction of thermistor R4 and trim resistor R3 is connected to the base electrode of transistor T2. Resistor R3 is trimmed so that there is insufficient voltage to the base of transistor T2 to turn it on before the threshold temperature is reached. This provides a high impedance state of the latch between

points 1 and 2.

As the threshold temperature is reached the resistance of thermistor R4 becomes low enough to just turn on transistor T2 through trim resistor R3. This turns on transistor T1 and latches through resistor R2. Once latched the circuit maintains a low impedance between points 2 and 3 until negative supply voltage -V to thermistor R4 is removed and re-applied. Capacitors C1 and C2 are included to minimize spurious latch triggering.

Thermistor R4 may be mounted on a suitable support such as a sheet or substrate of ceramic or other insulating material. The complete ceramic substrate may be actively trimmed to provide an accurate switching temperature. This may be done by placing the substrate on a controlled temperature hot block and trimming resistor R3 until latching occurs.

In order to turn off the pump at the threshold or latch temperature point 3 of the thermal switch means may be applied to a pump control system shown in Figure 4 to trigger capacitor C7, or alternatively to triac trigger control zener diode D4.

The thermal switch may be physically located with flow sensor 13 shown in Figure 9, within flow coupling element 34. The thermal switch may be physically soldered to the bottom of flow sensor 13 ie. remote from the water side, to measure water temperature.

In summary, the following commercial benefits may be readily achieved by the control system of Figure 4 or 8:

* Thermal elements and bridge components may be inexpensively mass produceable utilizing thick film technology.
* Thick film (or thin film) hybrid assembly ensures safety isolation consistent with suitable electrical, physical and especially thermal diffusivity properties.
* The heater element provides the mains voltage dropping component eliminating an expensive power transformer.
* Improved mains power transient protection.

It will be appreciated that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the present invention.

CLAIMS

1. A detector for detecting flow of fluid comprising:

heater means operable to transfer thermal energy to a body of fluid with which said detector is associated;

first and second temperature sensing means each of which is operable to respond to the temperature of said fluid body;

said second temperature sensing means being spaced from said first temperature sensing means so that there exists a difference in said response of each said temperature sensing means at least while no fluid flows past said detector; and

means operable to detect a change in said difference in said response and any said change being representative of a change in the flow rate of said fluid body.

2. A detector according to claim 1 wherein at least one of said temperature sensing means is positioned relatively close to said heater and having means for establishing a substantially constant temperature differential between said at least one temperature sensing means and the other of said temperature sensing means.

3. A detector according to claim 2 wherein said means for establishing said temperature differential includes means for adjusting the rate at which said heater means transfers thermal energy to said body of fluid.

4. A detector according to claim 3 wherein said rate is adjusted by reference to temperatures sensed by said first and second temperature sensing means.

5. A detector according to any one of the preceding claims including third temperature sensing means located intermediate said first and second temperature sensing means and wherein said means to detect a change in said difference includes means for comparing the output of said third temperature sensing means with the output of at least one of said first and second temperature sensing means.

6. A detector according to claim 1 wherein at least one of said temperature sensing means is positioned relatively distant from said heater such that it responds to ambient temperature of said fluid body.

7. A detector according to claim 6 wherein said means to detect a change in said difference includes means for comparing outputs of said first and second temperature sensing means.

8. A control system for a fluid flow generator incorporating a flow detector according to any one of the preceding claims.

9. A control system according to claim 8 including means to disable said flow generator in the event that said change in the flow rate of said fluid body exceeds a predetermined threshold.

10. A pumping system comprising:

a) a pump for delivering fluid from a source to a service outlet;

b) a motor for driving said pump;

c) a fluid accumulator inter-posed between said pump and said outlet;

d) pressure responsive means associated with said fluid accumulator and adapted to run said motor whenever fluid pressure detected by said pressure responsive means falls below a preset level;

e) a flow detector positioned to at least sample a portion of fluid flowing to said outlet and operable to disable said motor whenever the rate of fluid flow passing through said flow detector falls below a predetermined threshold;

first timing means operable to run said motor and disable said flow detector for a first time period following connection of power to said motor; and

second timing means operable to run said motor and disable said flow detector for a second time period following detection that fluid flow through said flow detector is below said predetermined threshold.

11. A pumping system according to claim 10 wherein said first time period is approximately 30-60 seconds and said second time period is approximately 5-15 seconds.

12. Isolating means for use with a flow detector and operable to isolate the detector from spurious flow of

fluid, said isolating means comprising:

a baffle element having wall means;

said wall means defining first and second spaces from receiving flowing fluid in turn;

said first space having a flow receiving inlet and an outlet and said second space being disposed adjacent said outlet for receiving flowing fluid therefrom;

said wall means defining said first space having a generally converging configuration such that the area in cross section of said first space decreases in the direction of flowing fluid;

said wall means defining said second space having a generally uniform configuration in the direction of flowing fluid;

said wall means defining said first space having a plurality of apertures therein permitting fluid to flow into and out of said first space, the size and location of each aperture and the thickness of said wall means being such that spurious flow is essentially contained to said first space whereby when said flow detector is placed adjacent said second space it is substantially free of spurious flow.

13. Isolating means according to claim 12 wherein said first space is of generally frusto-conical configuration and said second space of generally cylindrical configuration.

FIG 1

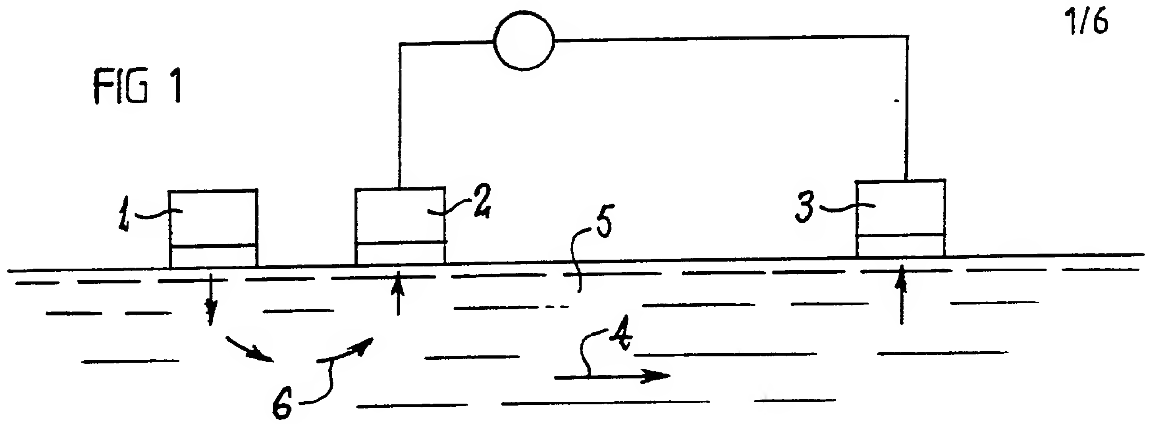


FIG 2

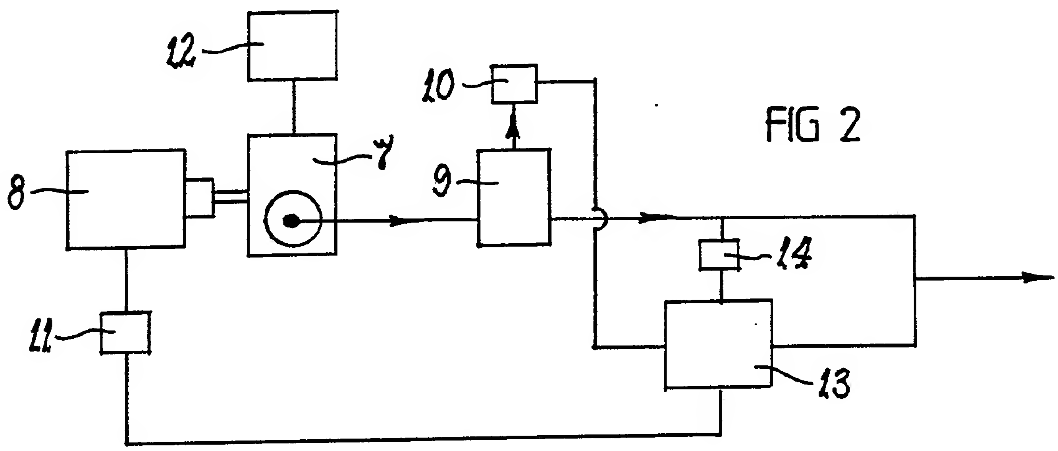
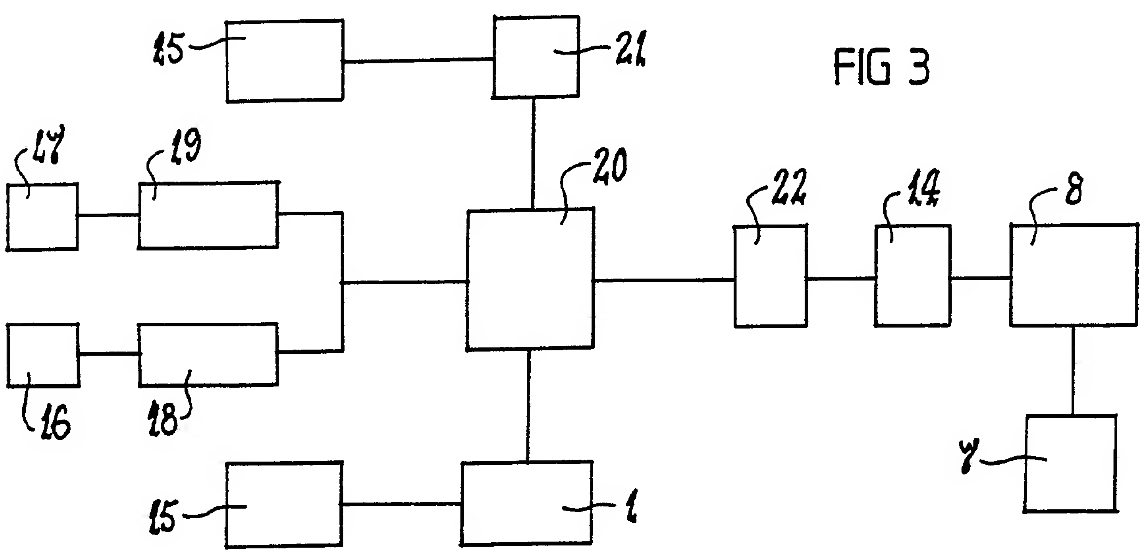
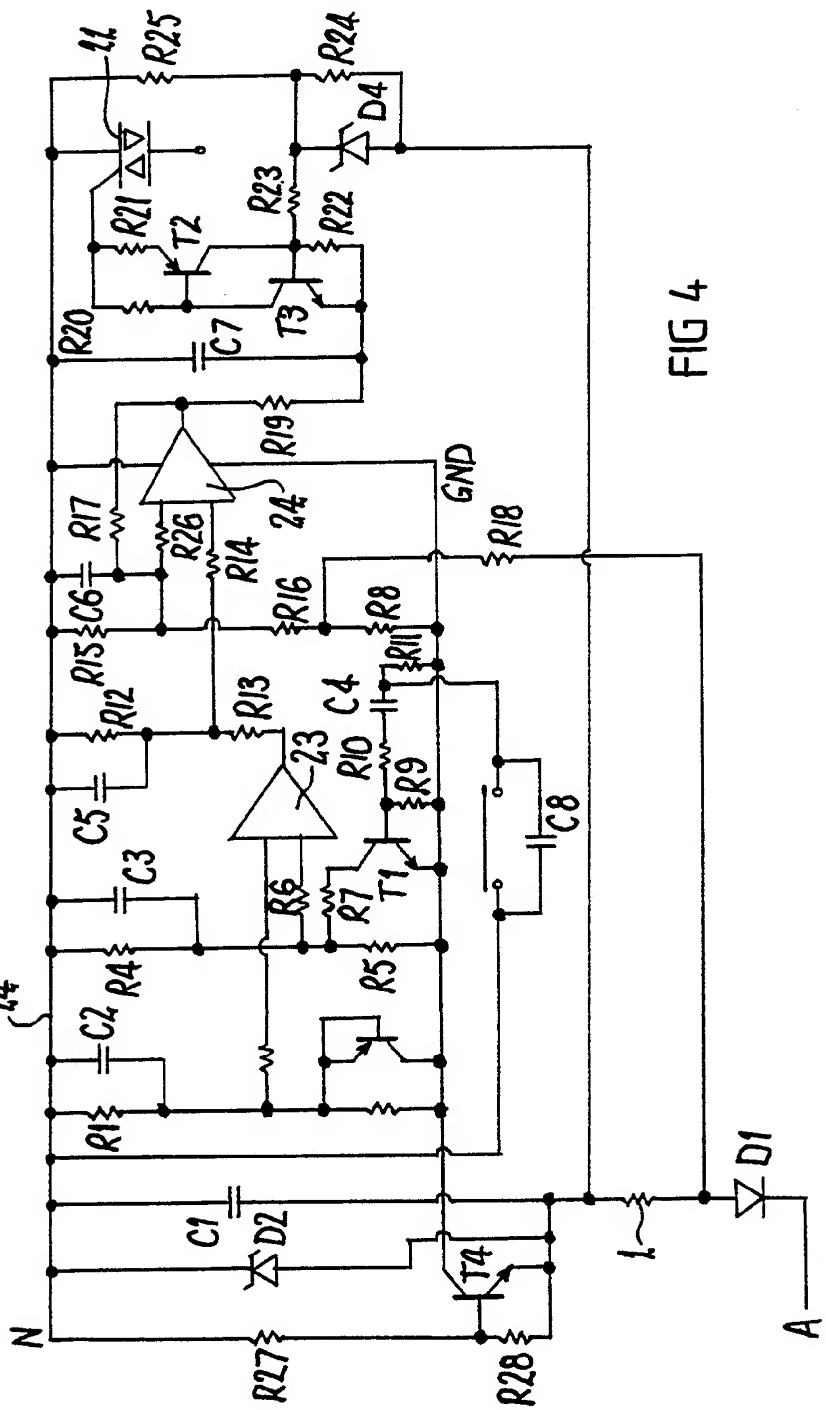


FIG 3





R25
R24
D4
R23
R22
R21
T2
T3
R20
C7
R19
R17
R26
R14
24
GND
R18
C6
R15
R16
R8
R12
R13
R11
C4
23
R10
R9
C5
C3
C8
R6
R7
T1
R4
R5
14
C2
R1
C1
D2
T4
D1
N
R27
R28
A

FIG 4

FIG 5

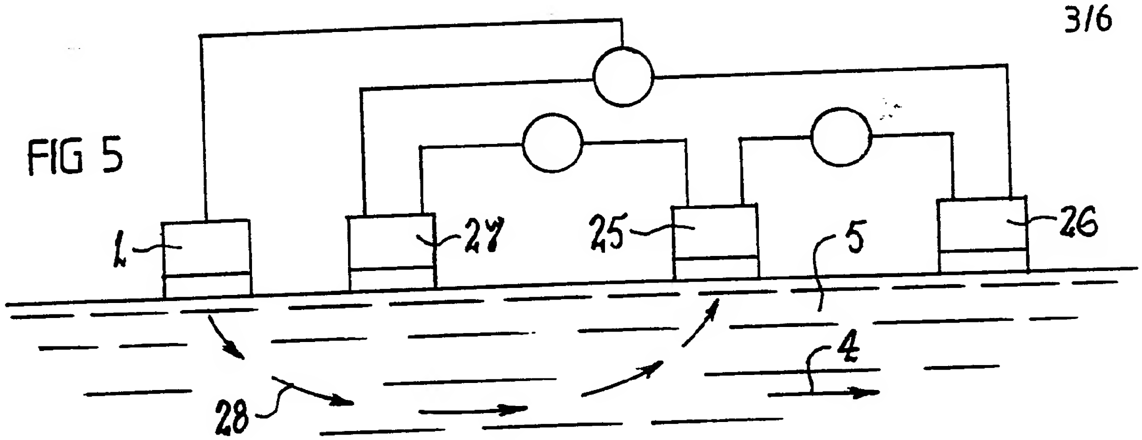


FIG 6

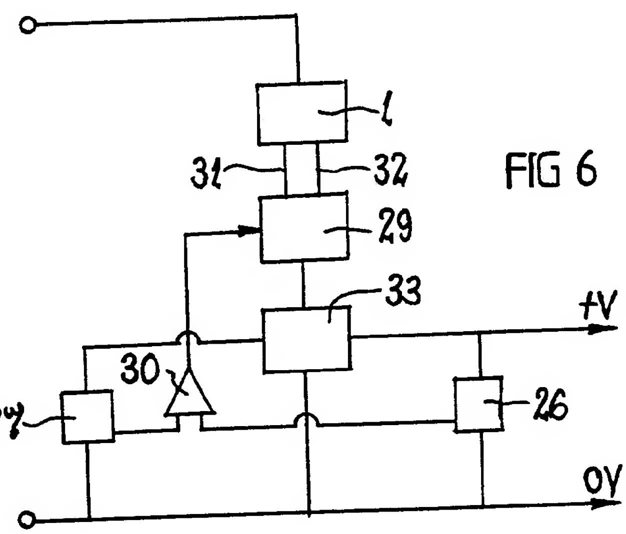
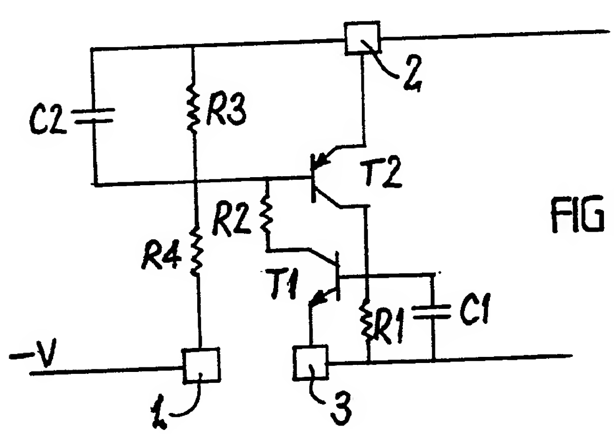


FIG 10



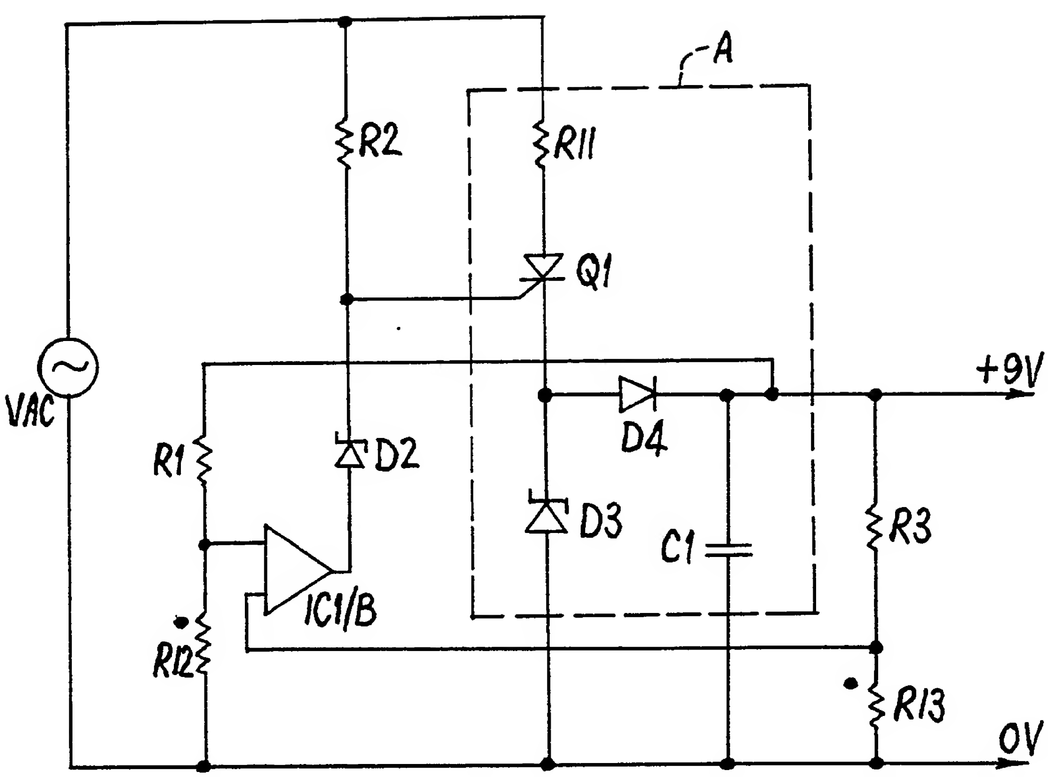
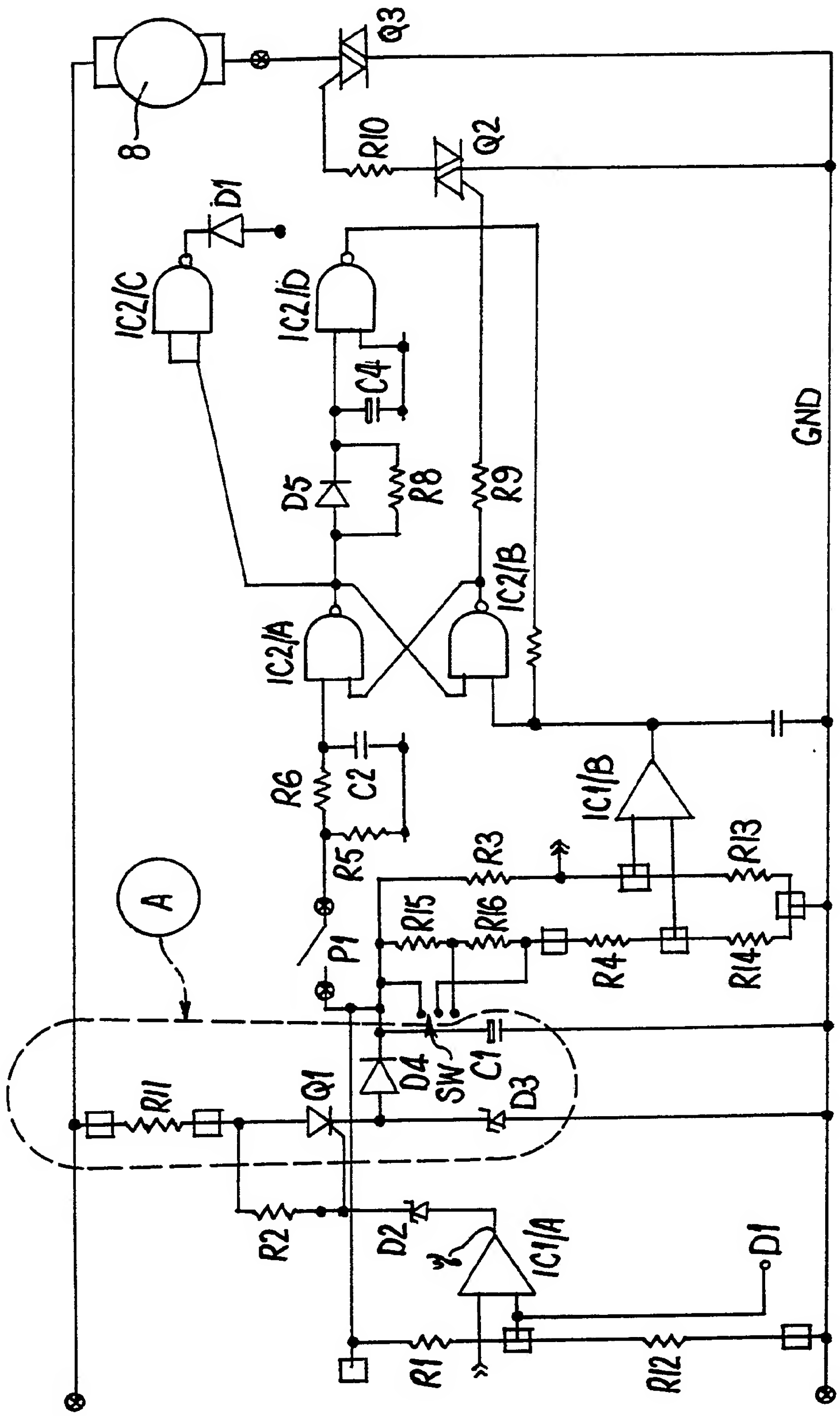


FIG 7


8
Q3
R10
Q2
D1
IC2/C
IC2/D
C4
D5
R8
R9
GND
IC2/A
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R6
C2
R5
IC1/B
R3
R13
A
P1
R15
R16
R4
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IC1/A
D1
R1
R12

FIG 8

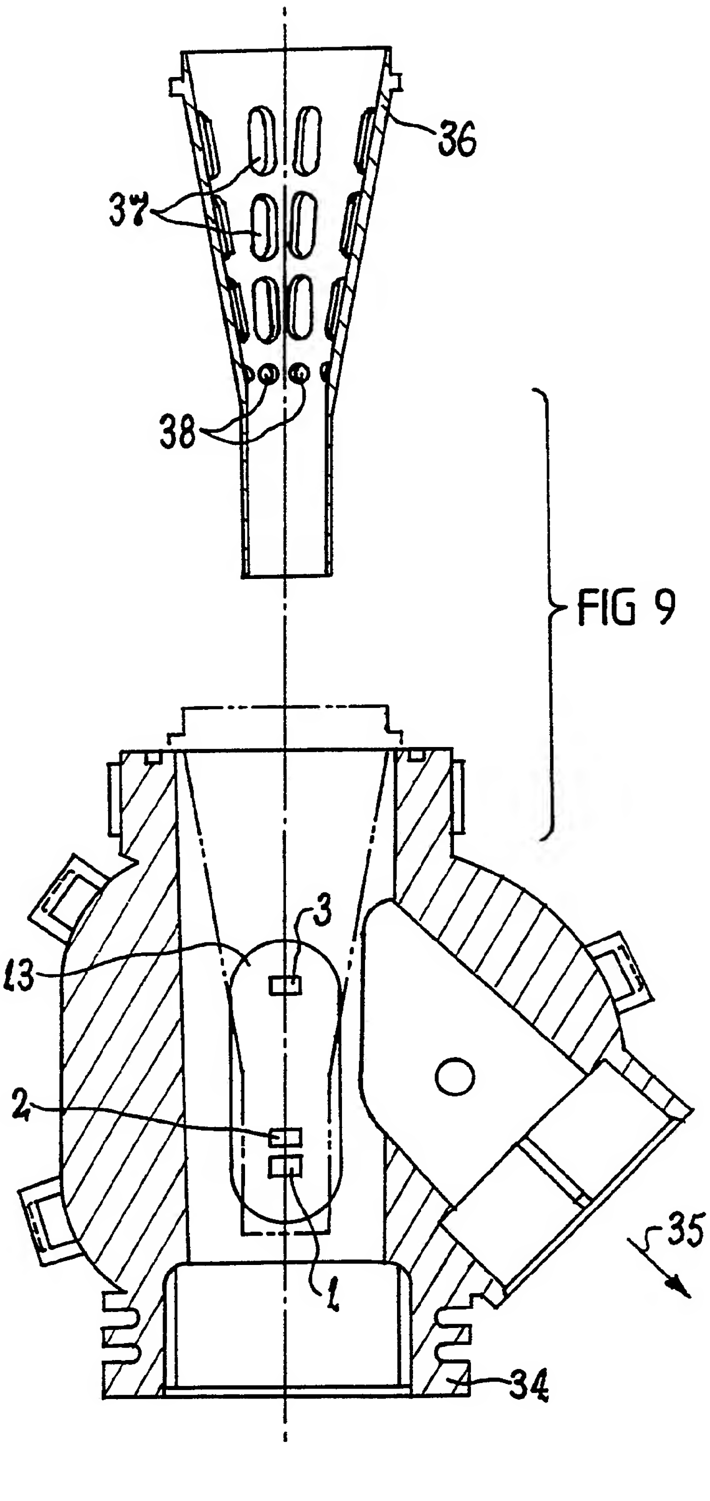

FIG 9

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 91/00239

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{5} G01F 1/68, F04D 15/00, F15D 1/02

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	G01F 1/68, F04D 15/00, F15D 1/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X,Y	US,A, 4733559 (AINE et al) 29 March 1988 (29.03.88) See claim 1	(1-7)
P,X	US,A, 4938079 (GOLDBERG) 3 July 1990 (03.07.90) See claims 1 & 3, column 6, lines 17-25, column 2, lines 54-64	(1-7)
X Y	US,A, 4255968 (HARPSTER) 17 March 1981 (17.03.81) See claim 1, Figs 1,4A,4C	(1-4,6,7) (5)
X Y	US,A, 4693116 (MIURA et al) 15 September 1987 (15.09.87) See claim 1, Fig 4A	(1-4,6,7) (5)
X Y	US,A, 3438254 (SEELEY) 15 April 1969 (15.04.69) See claim 1, column 1 line 54 - column 2, line 7	(1,6-9) (2-5)
	(continued)	

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
10 September 1991 (10.09.91)	17 September 91
International Searching Authority	Signature of Authorized Officer
Australian Patent Office	E. PERRIS

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	FR,A, 2500927 (CALVO) 3 September 1982 (03.09.82) See page 6, line 21 - page 9, line 22	(1-4,6-9)
X	FR,A, 2487973 (GOUMAIN) 5 February 1982 (05.02.82) See page 5, line 35 - page 8, line 27	(1-4,6,7)
X	FR,A, 2246846 (COUSIN et al) 2 May 1975 (02.05.75) See page 4, line 28 - page 6 line 7	(1-3,6,7)
X	DE,A1, 3518409 (KABUSHIKI KAISHA TOSHIBA) 28 November 1985 (28.11.85) See abstract, Fig 2	(1-4,6,7)
Y	GB,A, 1360225 (DISTILLERS COMPANY [CARBON DIOXIDE] LIMITED) 17 July 1974 (17.07.74) Page 1, line 66 to Page 2, line 14	(10)
Y	EP,A, 9428 (BALTIMORE AIRCOIL COMPANY, INC) 2 April 1980 (02.04.80) Page 5, line 25 to Page 6, line 13	(10)
Y	Patents Abstracts of Japan, M-783, Page 105, JP,A, 63-223392 (MITSUBISHI ELECTRIC CORP) 16 September 1988 (16.09.88)	(10)
Y	Patents Abstracts of Japan, M-647, Page 128, JP,A, 62-142890 (MATSUSHITA ELECTRIC IND CO LTD) 26 June 1987 (26.06.87)	(10)
X Y	DE,A, 1403256 (HAGAN CONTROLS CORP) 10 October 1968 (10.10.68) Page 6, line 8 to Page 7, line 15 and Figure 1	(1) (10)
X,Y	FR,A, 934793 (ROSENFENDER) 1 June 1948 (01.06.48) See page 1, line 56 to page 2, line 8 and page 3, line 56 to page 4, line 70	(10)
X	AU,B, 43654/79 (561099) (NEW ENVIRONMENT ENERGY DEVELOPMENT AKTIEBOLAG) 9 August 1979 (09.08.79) See page 2, lines 9 to 16 and page 3, line 13 to page 4, line 2 read in conjunction with Figure 4	(12-13)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. [ ] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[ ] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[ ] Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[ ] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [X] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

Claims 1-9 relate to a thermal differential flow rate sensor.
Claims 10,11 relate to a pump control system employing any known flow rate sensor.
Claims 12,13 relate to an isolating means employing a baffle element to control fluid flow and thus protecting any known flow rate sensor.

1.[X] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.[ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[ ] The additional search fees were accompanied by applicant's protest.

[X] No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 91/00239

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
US 4938079	CA 2011439	EP 386670	JP 3033620
US 4693116	JP 60001525		
US 4733559	US 4633578	US 4790181	US 4691566
US 3438254	DE 1553901		
DE 3518409	JP 60247171	US 4637253	JP 60247169
FR 2487973	DE 3130405 IT 1142593	ES 504933	ES 8206022
EP 9428	AU 50126/79 DE 2961699 US 4257745	BR 7905529 JP 55035199 ZA 7904642	CA 1115599 MX 147040

CONTINUED

INTERNATIONAL APPLICATION NO. PCT/AU 91/00239 (CONTINUED)

Patent Document Cited in Search Report	Patent Family Members					
AU 43654/79	DE	2902830	DK	362/79	ES	477284
	FR	2415729	GB	2013790	IT	1166600
	JP	54141932	NL	7900592	SE	7900241
	SU	1218930	US	4320304	ZA	7904122
	BE	873769	CA	1148477	SE	7801112

END OF ANNEX